

# Two Baseband Logarithmic Amplifiers Using Parallel Feedback Amplifier Cells

## 1. Research Objective

To design a DC-10 GHz logarithmic amplifier for use in fiber optic networks. The amplifier would be used in the optical single sideband system shown in Figure 1.

- The advantages of this system are:
- The optical signal power will not fade due to chromatic dispersion.
  - It has high spectral efficiency.
  - The noise contribution of optical amplifiers is reduced.

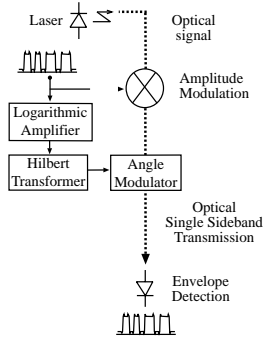


Figure 1: Phase modulation based optical single sideband.

## 2. Definition of a Logarithmic Amplifier

A log amplifier increments its output signal in response to some factor increase in the input signal.

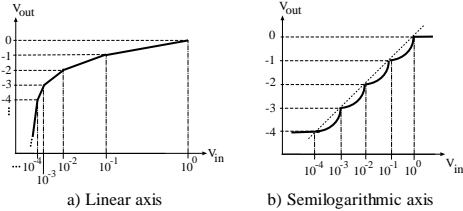


Figure 2: Log amplifier transfer function.

## 3. Log Amplifier Architectures

### 3.1 Branch Architecture

The branch architecture, shown in Figure 3, is a new wideband architecture developed by the authors. The gain through each amplification path is chosen using a novel design procedure. The breakpoints of the amplifier's transfer function lie on a logarithmic curve whose equation is given by:

$$V_{out} = V_{slope} \log_A \frac{V_{in}}{V_{intercept}} \quad (1)$$

where  $A$ ,  $V_{slope}$ , and  $V_{intercept}$  may be designed through the choice of component values in the circuit implementation. The first implementation of this design was performed in conjunction with Nortel Networks and was fabricated in NT35. Recently, the authors from the University of Calgary designed a second implementation in silicon germanium. This implementation uses parallel feedback amplifier (PFA) cells, shown in Figure 4, which are a newly invented circuit. The PFA cells greatly increase the bandwidth of the overall logarithmic amplifier. The die plots of the two branch log amplifier designs are shown in Figure 5.

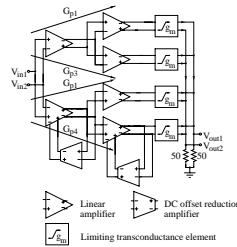


Figure 3: Branch logarithmic amplifier.

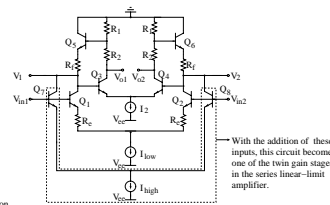
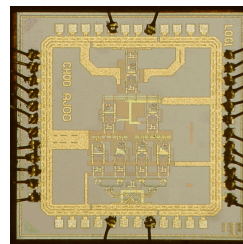
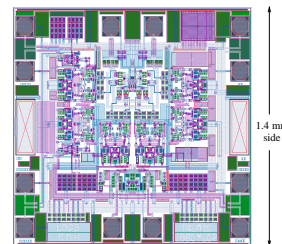


Figure 4: Parallel feedback amplifier.



a) NT35 design



b) SiGe design submitted for fabrication

Figure 5: Branch logarithmic amplifier implementations.

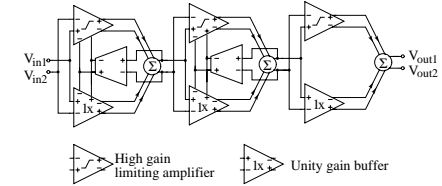


Figure 6: Series linear-limit architecture.

### 3.2 Series Linear-Limit Architecture

This topology, shown in Fig. 6, is the most widely used and consists of a cascade of high gain limiting amplifiers in parallel with a low gain path.

Previously, the presence of the low gain path has made the bandwidth too low for broadband applications. However, the authors have developed an implementation of the twin gain cell also based on the parallel feedback amplifier in Fig. 4. A die plot of the silicon germanium prototype is shown in Fig. 7.

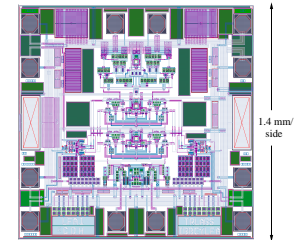


Figure 7: Series linear-limit SiGe design submitted for fabrication.

## 4. Results

The log amplifiers were designed to have 50 Ohm input and output impedances to allow for easy testing in a microwave system. Fig. 8 shows a photograph of the circuit test fixture.

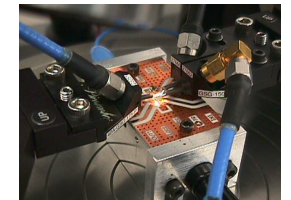


Figure 8: Log amplifier test fixture.

The small signal gain of the log amplifiers is shown in Fig. 9. The measured bandwidth of the NT35 log amplifier is 4 GHz, which represents the highest bandwidth to date for a silicon logarithmic amplifier, to our knowledge. Also shown is the simulated small signal gain of the silicon germanium log amplifiers. These circuits have a small signal bandwidth of 10.8 and 11.7 GHz for the branch amplifier and the series linear-limit amplifier respectively.



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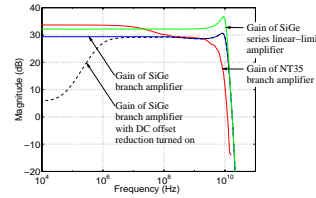


Figure 9: Small signal gain of the log amplifiers.

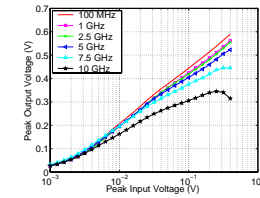


Figure 10: One-tone response of the SiGe branch log amplifier.

The one tone response of the SiGe branch amplifier is shown in Fig. 10. The circuit exhibits logarithmic linearity up to 7.5 GHz. To our knowledge, this is a 50% higher bandwidth than any log amplifier reported to date, as shown in Table 1. Furthermore, Fig. 11 shows the transient response of the SiGe log amplifier at 10 GHz. There is little distortion even at this frequency, despite the high power 1 V<sub>pp</sub> output signal.

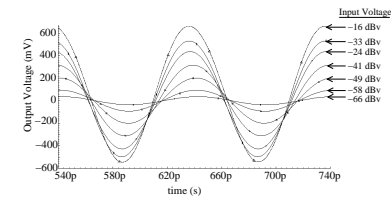


Figure 11: Transient response of SiGe branch log amplifier.

Patent Applied For

Circuit	Large Signal Bandwidth	Rise/Fall Time
Smith [1988]	0.5 – 4 GHz	500 ps/ 500 ps
Okii [1988]	DC – 3 GHz	400 ps/ 400 ps
This Work - SiGe Series Linear-Limit Amplifier	DC – 4 GHz	100 ps/ 100 ps
	DC – 5 GHz	50 ps/ 50 ps
	DC – 7.5 GHz	50 ps/ 50 ps
	DC – 7.5 GHz	50 ps/ 50 ps

Table 1: Comparison of microwave non-demodulating log amplifiers.

## 5. Summary

Two broadband SiGe log amplifiers have been described. The combination of SiGe technology and the use of parallel feedback amplifier cells promises to produce log amplifiers that have nearly double the bandwidth of previously reported results. These circuits are a key part of the optical transmission system in Fig. 1.

## 6. Acknowledgements

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